Hydrological Assessment of West Lake

Prepared for
Wolfden Resources Inc.

May, 2006

Reference: **GLL 51013**

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May 15, 2006

Mr. Phillipe di Pizzo
Executive Director
Nunavut Water Board
P.O. Box 119
Gjoa Haven, Nunavut
X0E 1J0

Dear Mr. di Pizzo:

Re: Ulu Exploration Project – Hydrological Assessment of West Lake

On behalf of Wolfden Resources Inc. we are pleased to provide you with two bound copies of the report Hydrological Assessment of West Lake for the Ulu Exploration Project, as required under Water Licence NWB1ULU008.

If there are any questions regarding this report, or if you require any additional assistance, please contact the undersigned.

Yours very truly,
GARTNER LEE LIMITED

Leslie Gomm, Ph.D., P.Eng.
Senior Environmental Engineer

LSG:lg

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Executive Summary

Wolfden Resources Inc. (WRI) is currently undertaking an advanced exploration program at the Ulu Mine site located in Nunavut. Under Water License NWB1ULU008 (expiry June 30, 2008), WRI is authorized to use water and dispose of waste for the purposes of advanced exploration, subject to the restrictions and conditions contained within the Licence. One of the conditions of the licence (Part C, Clause 4) requires the licensee to conduct a hydrological assessment of West Lake. Gartner Lee Limited (GLL) carried out the hydrological assessment and evaluated the effects on fish habitat of pumping water from West Lake under different annual precipitation scenarios.

West Lake is a small lake 500 m east of the Ulu camp. The lake drains an area of 1.3 km^2 and 10% of the drainage basin is lake area, almost all of which is West Lake itself. In the 2005 field season, bathymetry, precipitation and lake elevation data were collected on-site. In addition RWDI Air Inc. (RWDI) in cooperation with GLL had conducted a climate assessment of the region as part of a larger environmental assessment of the area. The climate assessment was used to establish the Mean Annual Precipitation, extreme annual precipitation values and evaporation values for West Lake.

The hydrological assessment included a water balance based on field data collected in 2005 and the climate assessment performed by RWDI. The water balance was then used to predict the change in lake elevation given average and dry years and low and high pumping rates. The model indicates that pumping the maximum allowable volume under the water licence will not significantly impact the lake elevation or fish habitat.

1. Introduction

Wolfden Resources Inc. (WRI) is currently undertaking an advanced exploration program at the Ulu Mine site located in Nunavut (Figure 1). Under Water License NWB1ULU008 (expiry June 30, 2008), WRI is authorized to use water and dispose of waste for the purposes of advanced exploration, subject to the restrictions and conditions contained within the Licence. Under Part C (Conditions Applying to Water Use), Item 4 states:

> *Within six (6) months following notification to the Board by the Licensee that operation at the site will resume, the Licensee shall submit to the Board Terms of Reference for hydrological assessment of West Lake, including an implementation schedule.*

West Lake is located approximately 500 m east of the Ulu Camp and serves as a source of drinking water for the camp. The primary inputs to the lake are from surface runoff and a stream that originates from a small lake upstream of the road. The License allows maximum daily water taking of 100 m^3. Gartner Lee Limited (GLL) was retained by WRI to develop the Terms of Reference and carry out the approved hydrological assessment of West Lake. The Terms of Reference for the hydrological assessment were submitted to the Board on March 24, 2005 and approved November 5, 2005.

2. Scope of Work

The objective of the hydrological assessment was to determine the potential environmental impact of the water withdrawal and subsequent changes in lake water level from natural water levels. The scope of work included:

Task 1 – Review and Compilation of Existing Information
Collection and review of relevant, available information on the West Lake and the Ulu site. This included a review of baseline information collected previously by RL&L as well as any recent information generated during the 2004 / 2005 baseline sampling program being carried out as part of the broader High Lake baseline program and ongoing West Lake pumping records from the site.

Task 2 – Climate Data Compilation and Analysis
Collection, review and summarization of local climate data generated from the climate station established at Ulu in June 2004. Collection, review and interpretation climate data from regional climate stations, and through regional analysis and local site data, characterization of the annual precipitation for Ulu including mean, wet and dry year cases. This work was carried as part of the 2004 / 2005 baseline work.

Task 3 - Bathymetry
Completion of a bathymetric survey of West Lake with a Garmin GPSMAP 230 Chartplotter / Depth Sounder . This data was used to develop a storage-capacity relationship for the lake.

Task 4 – Hydrological Data Collection
Establishment of a water level logger station in West Lake which provided a continuous record of lake elevation during the open water season. In addition, the elevation of West Lake and all lake inputs and outlets were manually surveyed over the season. Flow measurements were taken where possible. This work was carried out in conjunction with the 2005 hydrological baseline assessment work.

Task 5 – Water Balance
Based on the information provided from the tasks outlined above, a water balance was developed for the lake based on mean, and different extreme dry year conditions. The water balance provides resultant lake water elevations for the various cases including natural water level fluctuations.

Task 6 – Fish and Fish Habitat Assessment
Critical to the hydrological assessment is the impact of changes in lake water levels on fish habitat particularly in the shoreline areas. Fisheries assessment work carried out previously by RL&L determined that fish inhabit West Lake, specifically lake trout. As part of this study a fish and fish habitat assessment was completed to delineate fish species presence and important areas of fish habitat, including the shoreline areas. This work was done in conjunction with ongoing baseline fisheries work.

Task 7 – Impact Assessment of Water Withdrawal
Upon completion of the tasks outlined above an assessment of the impacts of water withdrawal from West Lake was carried out, specifically the impact of changes in water levels from natural conditions on fish and fish habitat.

In 2004, WRI retained GLL to conduct baseline field work to support the preparation of an Environmental Impact Statement (EIS) for a larger project, known as the High Lake Project, which includes the Ulu property, as well as the High Lake property and a proposed dock site at Grays Bay. The local site data presented in this report were collected in conjunction with this field work. GLL sub-contracted the climate and the hydrological components of the High Lake Project EIS to RWDI Air Inc. (RWDI) and Northwest Hydraulic Consultants (nhc), respectively, and some of this work has been incorporated into the enclosed West Lake hydrological assessment report.

3. Setting

The Ulu property is located in the Kitikmeot region of Nunavut about 550 km NNE of Yellowknife, NWT and 100 km south of Grays Bay on the Coronation Gulf of the Arctic Ocean. Nearby population centers include: Kugluktuk (Coppermine) located approximately 175 km WNW; Umingmaktok (Bay Chimo) located approximately 128 km ENE on the eastern side of Bathurst Inlet; Kingaok (Bathurst Inlet) located approximately 135 km ESE on the western side of Bathurst Inlet; and, Ikaluktiak (Cambridge Bay) located approximately 300 km NE of the High Lake project area including Ulu (Figure 1).

The Ulu area is located in a zone of continuous permafrost. During the warmer summer months, the uppermost layer of sediment is able to thaw. This active layer varies from less than 0.5 m depth in organic and insulated clay sediments to over 1.0 m in sand and gravel deposits. Ground ice contents at the base of the active layer vary between 40% to nearly 100% in some marine clays. These high ice contents likely form as surface water infiltrates the sediment through cracks and joints during the summer months, freezing to the permafrost as temperature drops in the winter (Rampton and Thomas 1993).

The climate in Canada's Arctic is arid and cold. From December to April, the region is in darkness. January and February are the coldest months and the winter is the driest season. Light begins to return to the Arctic slowly after the winter solstice and more quickly after the spring equinox. However, temperatures only begin to increase in May and June. By late May and early June the mean temperature is above 0°C and there are no sunsets. Over the summer months of July and August, mean daily temperatures remain relatively constant at 4°C. July and August are usually the wettest months but snow may occur. By mid October, the mean daily temperature is well below zero. This time period is considered the stormiest with the greatest snowfall occurring during September and October (RWDI).

4. Existing Conditions

4.1 Climate

Climate data for the area around the Ulu site have been collected by a range of agencies and over a variety of time periods. Most recently, WRI commissioned two climate stations, which has been operational since June 2004: one at Ulu adjacent to airstrip and one at High Lake. In addition to local data, regional data has been collected by Environment Canada for long periods of record at Kugluktuk, Cambridge Bay, and for a shorter length of time at the Lupin Mine site. Climate assessments for other resource developments in the region also exist, specifically, assessments for the Diavik and Jericho diamond projects and the Doris North gold project. RWDI has assessed the regional climate data available for the Ulu area as part of the larger baseline work associated with the High Lake Project. The data presented in the following section is a brief summary of the data presented in "Updated Report High Lake Climate Assessment," (RWDI 2006).

4.1.1 Available Data

Table 1 presents the meteorological monitoring locations that were included in the climate assessment conducted by RWDI.

Table 1. Summary of Meteorological Monitoring Locations and the Associated Meteorological Parameters (Table 3.1 RWDI)

Station	Cambridge Bay	Kugluktuk	Coppermine	Lupin	Contwoyto Lake	High Lake	Ulu
Location	69° 06' N 105° 07' W	67° 49' N 115° 08' W	67° 50' N 105° 07' W	65° 45' N 111° 15' W	65° 29' N 110° 22' W	67° 20' N 110°50' W	66° 55' N 116°58' W
Elevation m (ASL)	27	23	9	490	451	330	460
Time Period	1931-2004	1978-2004	1933-1977	1982-2004	1959-1981	2004-2005*	2004-2005*
Temperature	✓	✓	✓	✓	✓	✓	✓
Wind Speed	✓	-	-	-	-	✓	✓
Wind Direction	✓	✓	-	-	-	✓	✓
Rainfall	✓	✓	✓	✓	✓	-	✓
Snowfall	✓	✓	✓	✓	✓	-	-
Total Precipitation	✓	✓	✓	✓	✓	-	-
Snow Depth	✓	✓	✓	✓	✓	-	-
Relative Humidity	✓	-	-	-	-	✓	✓
Solar Radiation	✓	-	-	-	-	-	-

4.1.2 Temperature

RWDI assessed the temperature data collected at Cambridge Bay, Coppermine, Kugluktuk, Contwoyto Lake and Lupin, and compared that data to the 2004 and 2005 data collected at the Ulu and High Lake stations. The Ulu and High Lake temperatures fall within the range observed at the surrounding stations. Given the short period of record at Ulu and High Lake, RWDI could not predict long-term temperature statistics at the project area with a high degree of certainty. RWDI (2006) presents expected extremes and mean temperatures for the High Lake Project area (includes Ulu) based on the minimum and maximum of the extreme temperatures from the five locations listed above. The mean monthly temperatures were calculated based on the average of the mean monthly temperatures from Cambridge Bay, Coppermine, Kugluktuk, Contwoyto Lake, and Lupin. The recommended temperatures are consistent with those provided in the other climate reviews.

Table 2. Representative Temperatures for the High Lake Project Area (Table 3.2 RWDI Report)

Month	Air Temperatures		
	Extreme Hourly Minimum	Mean Monthly	Extreme Hourly Maximum
January	-52.8	-30.1	7.8
February	-53.9	-30.2	1.1
March	-53.3	-27.0	0.5
April	-43.9	-17.8	18.5
May	-35.0	-6.2	23.8
July	-2.2	10.1	34.9
August	-8.9	8.3	29.4
September	-20.0	2.0	26.1
October	-35.4	-8.2	13.9
November	-42.6	-20.6	5.0
December	-49.4	-26.8	4.4
Annual	-53.9	-11.8	34.9

4.1.3 Precipitation

Table 3 summarizes the Mean Annual Precipitation (MAP) at the Environment Canada stations included in the "Updated Report High Lake Climate Assessment," (RWDI 2006). The values presented have been corrected for undercatch. Undercatch in the Ulu area has been estimated to be 26% (RWDI). The Coppermine station was replaced with the Kugluktuk station in 1978 and therefore the average of these two stations is also presented.

Table 3. Mean Annual Precipitation at Environment Canada Meteorological Stations

Site	Rain (mm)	Snow (mm)	Mean Annual Precipitation Corrected for Undercatch (mm)	Percent Rain/Percent Snow
Cambridge Bay	87	100	187	46:54
Coppermine	145	145	289	50:50
Kugluktuk	168	212	309	54:46
Average: Coppermine & Kugluktuk	156.5	178.5	299	52:48
Lupin	205	172	378	54:46
Contwoyto Lake	164	154	318	52:48

Table 4 summarizes the monthly distribution of annual precipitation. Precipitation is divided relatively evenly over all the months except July, August, September and October, which have notably higher distribution of precipitation.

Table 4. Monthly Distribution of Total Precipitation at Environment Canada Stations

Month	Lupin	Kugluktuk	Coppermine	Contwoyto Lake	Cambridge Bay	Average Distribution
Jan	3%	5%	5%	3%	4%	4%
Feb	3%	4%	3%	4%	3%	3%
Mar	4%	4%	5%	4%	4%	4%
Apr	5%	5%	6%	4%	4%	5%
May	6%	8%	6%	7%	6%	7%
Jun	9%	6%	9%	11%	9%	9%
Jul	15%	15%	14%	14%	16%	15%
Aug	20%	16%	18%	16%	19%	18%
Sep	15%	16%	12%	13%	13%	14%
Oct	10%	11%	11%	12%	11%	11%
Nov	5%	5%	7%	6%	6%	6%
Dec	5%	5%	5%	4%	4%	5%

To some degree, precipitation in the arctic appears to be a function of latitude. The Arctic Ocean coast acts as a natural divide between two ranges of precipitation with a drier trend to the north east and a zone of heavier precipitation to the south (Energy Mines and Resources, 1991). A Mean Annual Precipitation (MAP) of 280 mm has been adopted for the High Lake Project area. This value takes into consideration the latitude of High Lake, which is similar to that of Kugluktuk, the proximity to the Arctic coastline, and the longitude of the site, which is approximately 175 km east of Kugluktuk. Table 5 presents the predicted extreme MAPs for the site based on the above discussion.

Table 5. Extreme Mean Annual Precipitation at Ulu

Return Period (years)	High (mm)	Low (mm)
2	280	280
5	320	240
10	344	216
20	360	198
50	380	180
100	394	164

4.1.4 Evaporation

Evaporation rates were taken to be the same at Ulu as those predicted for the High Lake Project area as part of the baseline work completed by nhc, RWDI and GLL. Evaporation rates have been measured at a number of sites in the region. Upon evaluation of the regional evaporation rates, total annual evaporation for the High Lake site was assumed to fall between the values estimated for Jericho, those measured at Lupin and those values estimated for Doris North. It is expected that evaporation values in the High Lake area will be lower than Jericho and Lupin given High Lake's higher latitude.

Table 6. Monthly Evaporation for High Lake Project

Month	Evaporation (mm)
June	38
July	104
August	84
September	14
Total	240

4.2 Bathymetry

Bathymetric data was collected from West Lake (L528) on August 3, 2005 and are presented in Figure 2. West Lake has a perimeter of 2182.72 m, a volume of 417,010 m^3, a water surface area of 9.35 ha and a bottom surface area of 9.75 ha (based on 614 data points). The mean lake depth is 4.35 m, while the maximum lake depth is 13.63 m and the approximate average ice depth is 1.75 m. Substrate is composed of: 3.08 ha of boulders; 1.23 ha of boulder/cobble; 0.55 ha boulder/cobble/fine; 4.93 ha of fines.

4.3 Hydrology

The drainage basin for West Lake, located 500 m east of the Ulu camp, is approximately 1.27 km^2 or 127 ha (Figure 3). The basin drains from south to north and has approximately 10% open water most of which is West Lake itself. The stream which flows into the lake from the south is small and flows through a culvert under the road just before flowing into West Lake. The streamflow at the inlet of the culvert is almost always impossible to detect or measure; however, streamflow at the outlet of the culvert has been observed in June and July, though not measured.

4.3.1 Snow Survey

Snow surveys were conducted in the Ulu area in 2004 and 2005. In 2004, three snow courses were established in the Ulu area and in 2005 the snow survey program was expanded to four snow courses (Figure 3). Each snow course comprised ten discrete snow measurements. Each snow survey was performed one-time only in May to establish snow-water equivalent prior to freshet.

Sample ID	Location	2004 Snow Water Equivalent (mm)	2005 Snow Water Equivalent (mm)
ULU-SN1	2.5 km SE of camp	40	52
ULU-SN2	400 m W of Meadow Lake	75	298
ULU-SN3	Ulu Camp	91	114
ULU-SN4	Ulu airstrip	N/A	94

4.3.2 Lake Levels

The level of West Lake was surveyed on June 18, 2005 and the survey was tied into a temporary bench mark. A Solinst Levelogger was placed at the outflow of West Lake on June 25, 2005. The water level in the lake dropped below the Levelogger location shortly thereafter. During the next field visit, field staff relocated the logger and took a manual survey of the lake level. Figure 4 shows the measured water elevations for 2005.

4.3.3 Streamflow

The outlet of West Lake is a wide boulder field in a shallow gulley. The boulders range from approximately 0.5 to 2 m in diameter. Streamflow is under these rocks and difficult to measure. In the spring of 2005 a small channel was located and streamflow was measured to be 0.04 m^3/s; however, it is possible that a large amount of flow was not included in this one channel. By early August, the second time field staff visited the site, it was not possible to measure streamflow, nor was there observed streamflow in September. However, given the nature of the outlet it is entirely possible that water was flowing under the rubble field. Figure 5, Figure 6, Figure 7, and Figure 8 show the outlet of West Lake in June and August.

4.4 Water Takings

West Lake provides the potable water for the camp at Ulu. The maximum allowable daily quantity of water that can be withdrawn from West Lake is 100 cubic meters. In 2005, the pumping volume was recorded daily or weekly. The average daily volume pumped out of the lake over the months of June to October was approximately 14 m^3/day. A copy of the original pumping records for 2005 are included in Appendix A.

4.5 Fish and Fish Habitat

West Lake was sampled for fish, fish habitat, primary and secondary producers and bathymetry on August 2 and 3, 2005. The following summarizes methodology employed to collect the data, as well as sampling results.

Food web sampling included collecting phytoplankton (primary producer) and benthic invertebrates (secondary producer). Phytoplankton composite samples were collected from the euphotic zone (two times the Secchi depth) with a continuous sampler. The resulting community abundance, presented as biovolume (mm^3/m^3), was found to be 101.7 mm^3/m^3, which was the second highest value found within the Ulu area during 2005 sampling. Species richness in West Lake was also the second highest (n=44) in the Ulu area. The phytoplankton sample was dominated by diatoms, of which the most prevalent diatom species, *Cyclotella comta,* is characteristic of low nutrient aquatic systems. Diatoms are unicellular organisms with cell walls that are made up of silica. They are also important components of the phytoplankton community as primary sources of food for zooplankton in both marine and freshwater habitats. In the Ulu area, lakes dominated by diatoms were able to achieve higher productivity.

Benthic invertebrates and secondary producers were collected by completing a five minute kick and sweep survey along a representative section of the western shoreline of West Lake. The dominant phylum was Arthropoda (84%), which is similar to community composition found in other adjacent lakes. Species richness was comparable to richness values found in other Ulu area lakes (n=6), while abundance was the lowest found in the area (n=7).

Resident lake trout (*Salvelinus namaycush*) in West Lake were caught in gill nets set during the day in both littoral and pelagic habitats at depths ranging from 0 m – 15.5 m. Fish caught ranged in size from 320 – 405 mm (fork length, x=358 mm, n=55) and in age from 9 to 18 years (x=12 years, n=5). Of those fish sampled, three males and two females were ripe for spawning. Intestinal parasites were observed in all fish caught.

Fish habitat in West Lake (L528) can be classified into four types:

- Rearing, which includes boulder/cobble and cobble substrates occurring at all water depths and is used by sub-adult fish for foraging and refuge;
- Spawning, which includes boulder and boulder/cobble substrates occurring at a depth below average ice thickness and is used for the specific act of spawning;
- Nursery, which includes boulder and boulder/cobble substrates occurring at a depth below average ice thickness, and is used by developing embryos and young of the year; and

- Foraging, which includes boulder, boulder/cobble, boulder/cobble/fines, boulder/fines and fine substrates occurring at all water depths and used by adult fish for feeding or periods between feeding.

5. Water Balance

A water balance for the West Lake drainage basin was developed to predict the potential effects of pumping on the lake elevation. The 2005 site data including snow survey, precipitation and lake elevation data were used to develop a stage – discharge relationship for the lake. Different annual precipitation and pumping rate scenarios were then tested by the model to predict the change in lake elevation due to pumping under different conditions.

5.1 2005 Inputs

Table 7 summarizes the data available for input to the water balance and Table 8 presents the actual data used to derive the water balance.

Table 7. Summary of Available Data for Water Balance Input

	Data Source	Period of Record	Units
Snow on Ground	Snow survey	May 24, 2005	mm snow water equivalent
Precipitation	Ulu Climate Station	June 2004 – September 17, 2005	mm/day
Evaporation	Assumed from modeling work by Northwest Hydraulics	Annual average on monthly basis	mm/month
Runoff Co-efficient	Range of 0.45 – 0.6 given from modeling work by NWH		
Lake Elevation	Solinst Levelogger installed at outlet	June 25-28; Aug 5 – Sept 15, 2005	
Lake Discharge	Derived from lake elevation and water balance	not measurable in the field	
Daily Pumping Volume	Camp records	June – September	Data varied from daily to weekly records
Elevation vs Volume	Bathymetry study conducted by GLL 2005		Depth in m from surface
Drainage Area	NTS mapping 1:20 000		

5.1.1 Precipitation

Precipitation is measured at the Ulu climate station by a tipping bucket rain gauge. Typically, rainfall measurements are underestimated due to adhesion of water to the gauge surface, evaporation, splash-out and wind losses. All of these losses are called undercatch. The precipitation measured at Ulu was adjusted by 26%, which is the undercatch proposed for the project area by RWDI. In addition, the precipitation at Ulu was also corrected by the undercatch at Kuglugtuk (21%) as Kuglugtuk is closer to the project area. The difference between the two on the West Lake level was negligible and 26% was adopted. Figure 4 includes the precipitation measured at the Ulu climate station.

5.1.2 Evaporation

The evaporation values were calculated by nhc for an average year and are:

June	38 mm
July	104 mm
August	84 mm
September	14 mm
Total	240 mm

5.1.3 Run-off Co-efficient

The run-off coefficient was allowed a range between 0.45 and 0.6. The predicted lake elevations most closely matched the observed lake elevations when a run-off coefficient of 0.5 was assumed.

5.1.4 Lake Discharge

Lake discharge was estimated based on the measured change in lake storage according to the Levelogger, measured precipitation, and estimated evaporation. The estimated streamflow was plotted against streamflow predicted by Manning's equation. Manning's equation appears to adequately predict flow out of West Lake as shown in Figure 9 given the following variable values:

Slope:	0.001
Roughness co-efficient (n):	0.06
Width:	4.5 m

The width of the lake outflow is approximately 45 m wide, however it was estimated that only 10% of the outlet is open space for flow given the size and number of large boulders (Figure 6, Figure 7 and Figure 8).

5.1.5 Sub-Surface Flow

Sub-surface flow was assumed to exist given that lake levels continued to drop over the course of the summer of 2005. This is based on the fact that despite the lake level falling below the assumed invert, the change in lake volume was greater than that estimated due to evaporation. Also, the water balance follows the measured lake levels more closely when some sub-surface flow is assumed. The sub-surface flow was estimated to be 0.002 m^3/s.

5.1.6 Lake Invert

The lake invert was assumed to be 238.75 m.a.s.l. This assumption is based on the surveyed level of the datalogger as well as the bathymetric mapping and how well the predicted lake elevations matched the observed lake elevations given an invert elevation ranging from 238.7 to 238.8.

5.1.7 Lake Elevation

The observed lake elevation fluctuated by approximately 0.4 m over the course of the open-water season in 2005. However, it is expected that the highest and lowest elevations were not measured by the Levelogger. The water levels in West Lake predicted by the water balance were compared to the water levels observed by the Levelogger. The results are presented in Figure 4.

Table 8. Summary of Measured and Estimated Data Input to 2005 West Lake Water Balance

	Snowmelt Estimated (mm)	Precip (mm)	Start Lake Elevation (m.a.s.l.)	End Lake Elevation (m.a.s.l.)	Evaporation (mm)	Pumping Volume (m^3)
June 14 - 30	114	51	239.15	239	19	145
July 1 - 15	0	11.68	239	238.86	52	92
July 16 - July 31	0	6.096	238.85	238.71	52	74
Aug 1 - Aug 8	0	43.436	238.7	238.77	21.6	50
Aug 9 - Aug 17	0	22.346	238.8	238.87	21.7	44
Aug 18 - Aug 31	0	6.096	238.86	238.76	35.1	100
Sept 1 - Sept 15	0	4.318	238.76	238.71	7	123

The data presented in Table 8 were all measured values with the exception of the evaporation values and the lake levels between the dates of June 29, 2005 and August 4, 2005.

Table 9 presents the data in Table 8 in volume form and includes the calculated flow out of the lake, which was taken to be the change in lake storage observed by the Levelogger plus the Net Input into the lake where the Net Input is Total Precipitation minus Total Evaporation.

Table 9. Summary of Volume Changes in West Lake 2005

	Total Precip Input	Total Evap Output	Start Lake Volume	End Lake Volume	Change In Lake Storage	Net Input (Total Precip – Total Evap)	Calculated Flow Out (Change in Lake Storage + Net Input)
	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)
June 14 - 30	114,485	2,236	429,662	424,585	5,076	112,104	117,180
July 1 - 15	8,104	6,120	425,301	420,563	4,739	1,892	6,630
July 16 - July 31	4,230	6,120	420,985	416,295	4,690	-1,965	2,725
Aug 1 - Aug 8	30,138	2,542	416,713	417,997	-1,284	27,546	26,262
Aug 9 - Aug 17	15,505	2,554	419,557	420,849	-1,292	12,907	11,614
Aug 18 - Aug 31	4,230	4,131	421,272	417,713	3,559	-2	3,557
Sept 1 - Sept 15	2,996	824	418,417	416,295	2,121	2,049	4,171

5.2 Assumptions

The following assumptions were made for the West Lake Water Balance Model:

- No inflow to lake other than surface runoff;
- All snowmelt occurs between June 14 and June 30;
- The precipitation distribution follows the run-off distribution observed at the site in 2004 and 2005:

June	49 %
July	35 %
August	10 %
September	6 %

- The pumping rate is constant;
- Evaporation is distributed evenly over each day of the month;
- The model uses a 2-day time step;
- Evaporation remains constant regardless of MAP;
- Evaporation calculations assumed a constant surface area of lake;
- Subsurface flow stops on Dec 1 and begins on June 7th;
- Ice thickness on the lake is 2m; and
- Ice forms on the lake Nov 1st and is off the lake June 1st.

Two operational scenarios were modeled for the withdrawal of water from West Lake:

- Summer only (June – September); and
- Spring to fall (May – November).

5.3 Results

The water balance was used to predict the lake elevation in response to normal and dry years, based on the annual precipitation values provided by nhc and RWDI, and lake elevations were also predicted for different pumping rates and the two different operational scenarios. The results are presented in Table 10 and Table 11.

Table 10. Summary of Lake Elevation Scenarios – Summer Operation Only (June 7 – Sept 30)

Annual Precipitation (mm)	Pumping Rate (m^3/day)	Lake Elevation at End of Operating Season	Lake Volume (m^3)	Percent Change in Lake Volume due to Pumping
280	0	238.81	419,842	No pumping
280	15	238.81	419,842	0
280	100	238.8	419,557	-0.07%
216	0	238.79	419,271	No pumping
216	15	238.79	419,271	0.00%
216	100	238.76	418,417	-0.20%
180	0	238.74	417,848	No pumping
180	15	238.72	417,280	-0.14%
180	100	238.64	415,016	-0.68%

Table 11. Summary of Lake Elevation Scenarios - Spring to Fall Operation (May 1 – Nov 30)

Annual Precipitation (mm)	Pumping Rate (m^3/day)	Lake Elevation at End of Operating Season	Lake Volume (m^3)	Percent Change in Lake Volume due to Pumping
280	0	238.42	408854	No pumping
280	15	238.38	407743	-0.27%
280	100	238.18	402236	-1.62%
216	0	238.4	408298	No pumping
216	15	238.36	407189	-0.27%
216	100	238.06	398967	-2.29%
180	0	238.36	407189	No pumping
180	15	238.29	405256	-0.47%
180	100	237.93	395455	-2.88%

6. Impact of Water Withdrawal

Depending on the amount of water being extracted from a lake, water withdrawal can result in a loss of fish habitat (e.g., oxygen depletion, loss of spawning habitat, loss of over-wintering habitat and/or reductions in littoral habitat). The Department of Fisheries and Oceans provides guidance for winter water extraction in the North (DFO 2005), which states that water taking should not exceed 5% of the available water volume of the lake. Based on current operating conditions at the site (~ 15 m^3/day) the water taking from West Lake is less than 1% of the water volume on an annual basis, with a maximum drawdown of 43 cm during low flow conditions. Based on these results, it is anticipated that the water withdrawl at West Lake should not cause a harmful alteration, disruption or destruction of fish habitat (HADD). Our estimated maximum extraction volume is estimated at 2.88% of the available lake volume, occurs during low flow conditions at the maximum pumping rate and is well below 5% of the available lake volume.

Table 12 provides as summary of the percent change in available water volume during the underice operational period (May and November only) for the Spring – Fall pumping scenario. During this period the water withdrawal from West Lake is still not estimated to exceed 5% of the available underice water volume, with a maximum change in water volume of 1.8%.

Table 12. Summary of Percent Change in Lake Volume due to Pumping during Under-Ice Conditions – Spring – Fall operations (May 1 – Nov 30)

Annual Precipitation (mm)	Pumping Rate (m^3/day)	Percent Change in Lake Volume during underice pumping (May and November only)
280	15	0.25%
280	80	1.40%
280	100	1.80%
216	15	0.25%
216	80	1.40%
216	100	1.80%
180	15	0.26%
180	80	1.40%
180	100	1.80%

7. References

Department of Fisheries and Oceans. 2005. DFO Protocol for Winter Water Withdrawal In the Northwest Territories.

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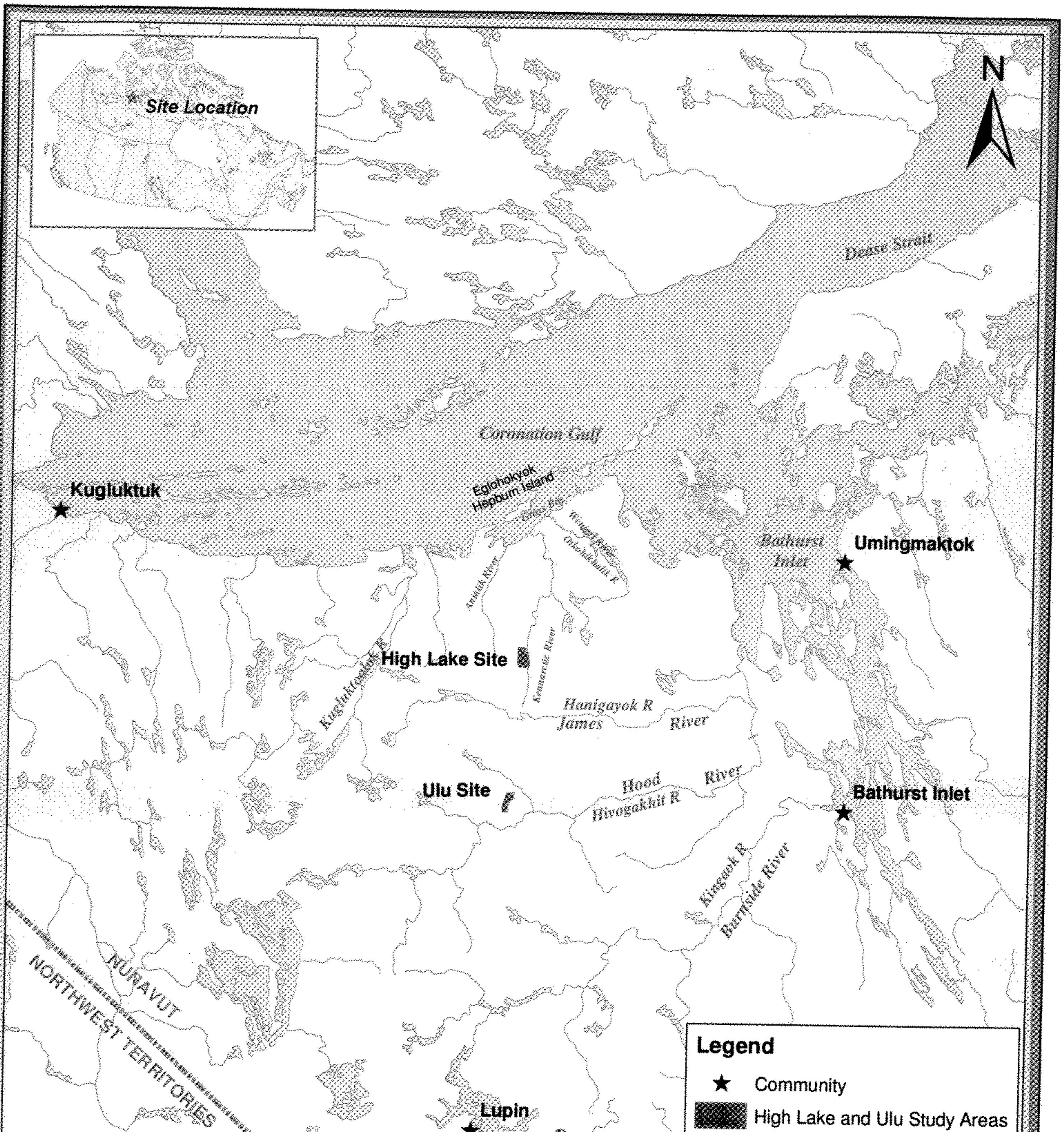
Rampton, V.N. and Thomas, R.D. 1993. Hepburn Island, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Open File 2662.

RWDI Air Inc. 2006. Updated Report High Lake Climate Assessment. Submitted to: Gartner Lee Limited Calgary, AB.

Figures



0 10 20 40 60 80 100 120 Km

1:2,000,000

Projection: UTM
Datum: NAD83 Zone 12
Reviewed by: EMcK
Prepared by: PW
Date: May, 2006
File: 51013_B1_06eMay10_Fig1R1_LocMap.mxd

Data Sources:
Hydrologic data based on field work conducted by Gartner Lee Limited during summer of 2004 and 2005.

Catch basins delineated by Gartner Lee are approximate and are based on 1:50,000 scale topographic data.

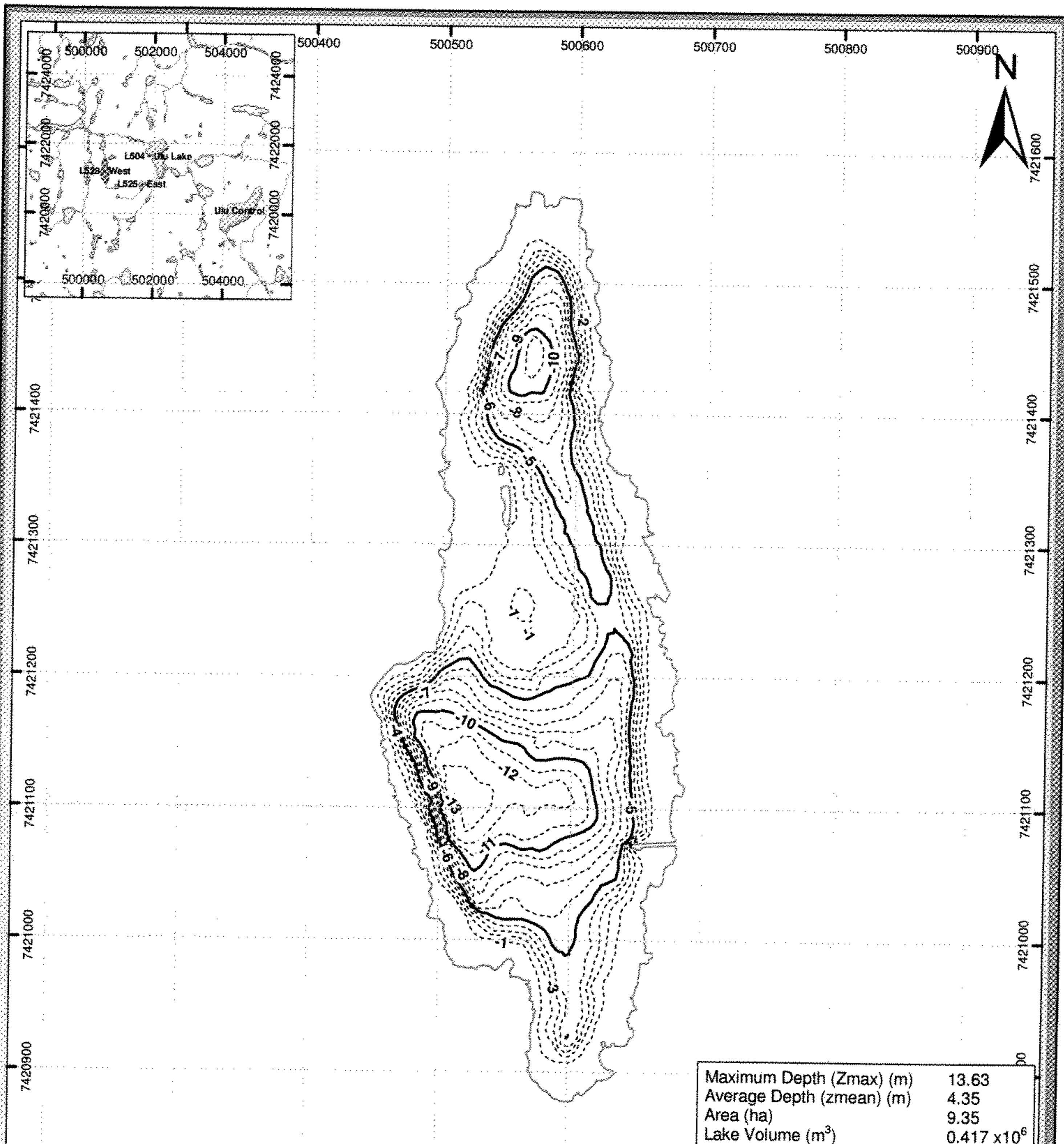
WOLFDEN Resources Inc.

Hydrological Assessment of West Lake
Ulu Exploration Project, Nunavut

Location of Ulu Site

Gartner Lee

Revision:	1
Figure No.:	1



Maximum Depth (Zmax) (m)	13.63
Average Depth (zmean) (m)	4.35
Area (ha)	9.35
Lake Volume (m^3)	0.417 $\times 10^6$

0 25 50 100 150 200 250 m

1:4,000

Projection: UTM
Datum: NAD83 Zone 12
Reviewed by: EMcK
Prepared by: PW
Date: May, 2006
File: 51013_B1_06eMay10_Fig3R1_West_Lake_Bathymetry.mxd

Data Sources:
Hydrologic data based on field work conducted by Gartner Lee Limited during summer of 2004 and 2005.

Catch basins delineated by Gartner Lee are approximate and are based on 1:50,000 scale topographic data.

WOLFDEN Resources Inc.

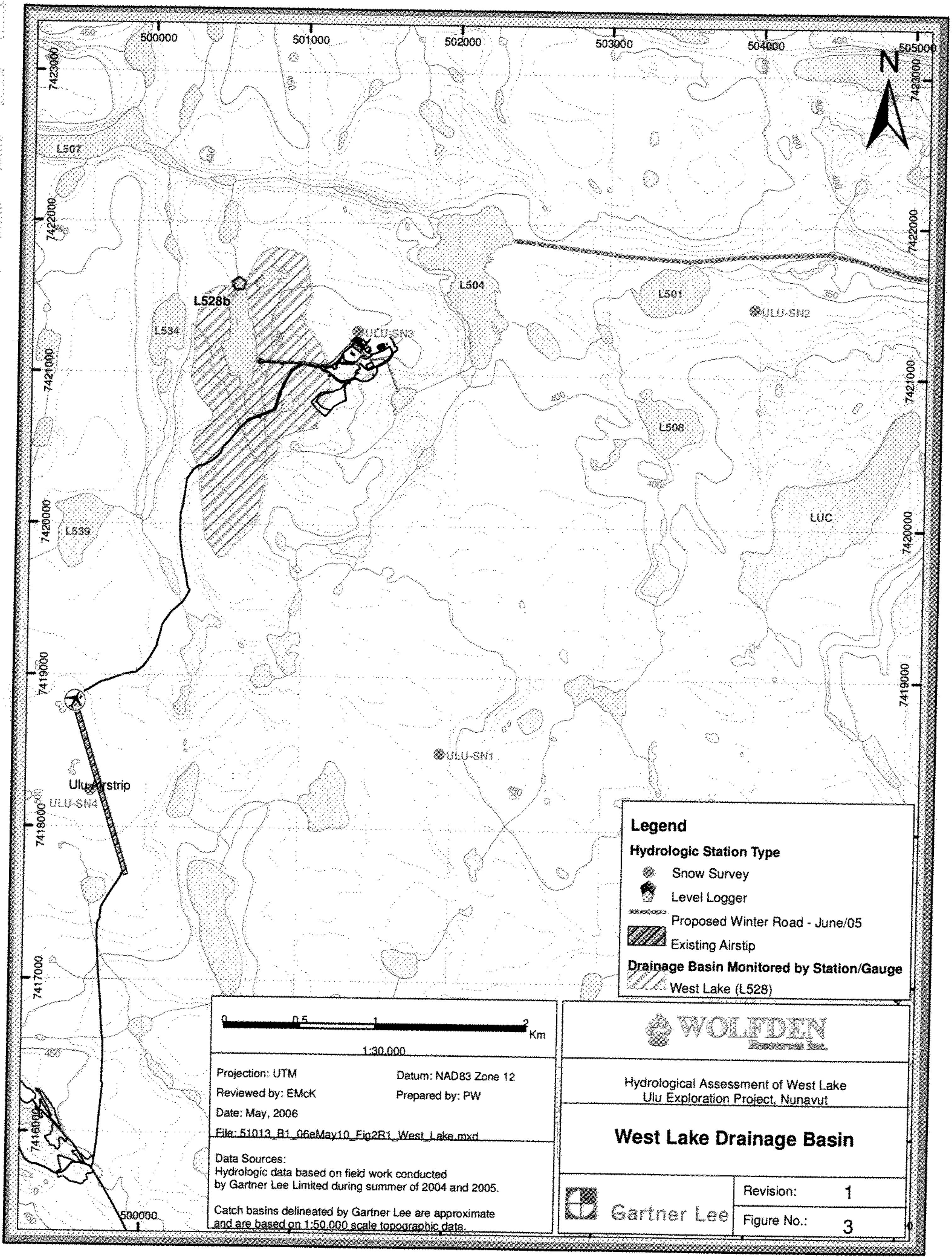
Hydrological Assessment of West Lake
Ulu Exploration Project, Nunavut

West Lake (L528) Bathymetry

Gartner Lee

Revision: 1

Figure No.: 2



500000
501000
502000
503000
504000
505000
7423000
7422000
7421000
7420000
7419000
7418000
7417000
7416000
N
L507
L504
L501
L528b
L534
ULU-SN3
ULU-SN2
L508
LUC
L539
ULU-SN1
Ulu Airstrip
ULU-SN4
Legend
Hydrologic Station Type
Snow Survey
Level Logger
Proposed Winter Road - June/05
Existing Airstip
Drainage Basin Monitored by Station/Gauge
West Lake (L528)
0 0.5 1 2 Km
1:30,000
Projection: UTM
Datum: NAD83 Zone 12
Reviewed by: EMcK
Prepared by: PW
Date: May, 2006
File: 51013_B1_06eMay10_Fig2B1_West_Lake.mxd
Data Sources:
Hydrologic data based on field work conducted by Gartner Lee Limited during summer of 2004 and 2005.
Catch basins delineated by Gartner Lee are approximate and are based on 1:50,000 scale topographic data.
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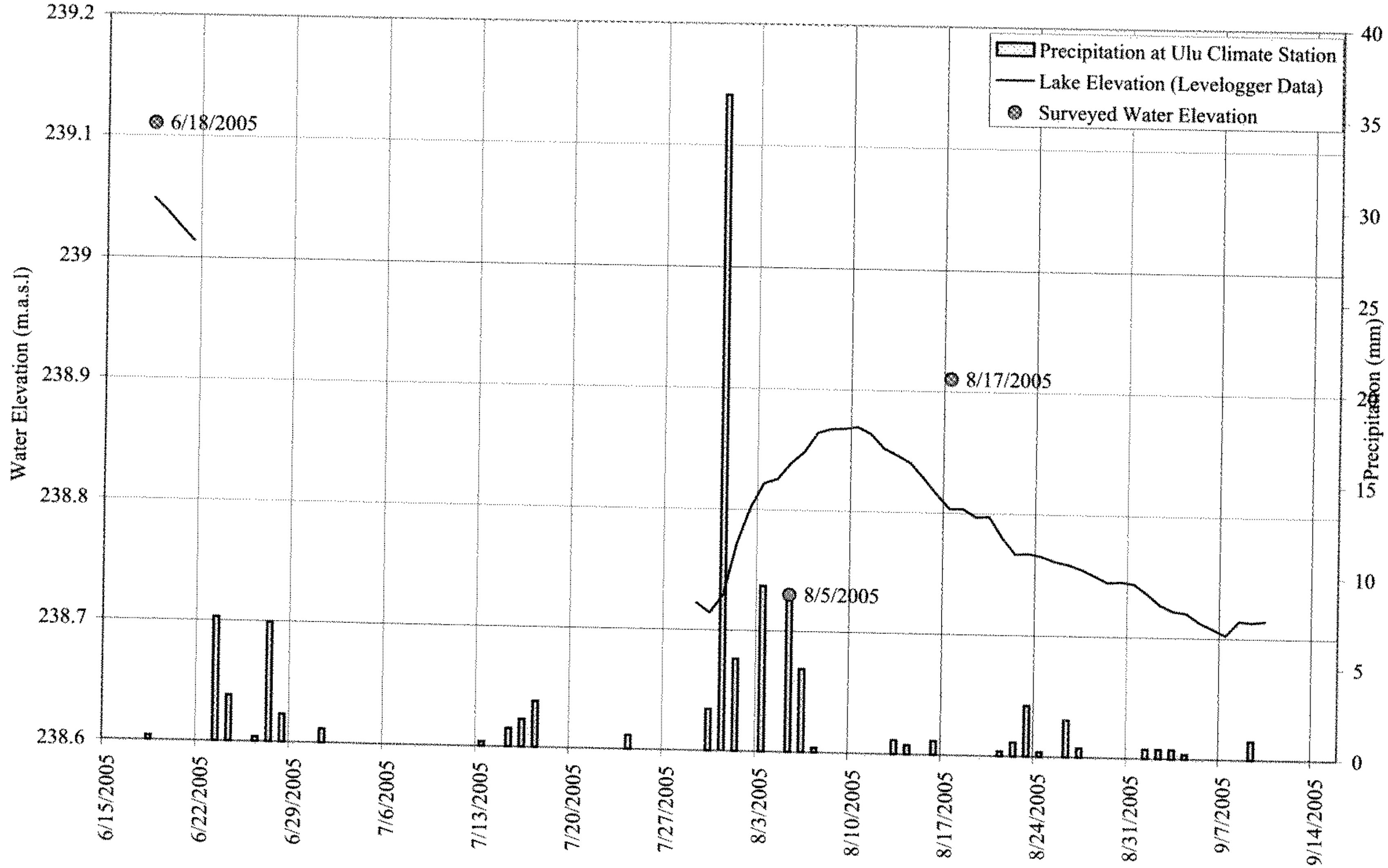
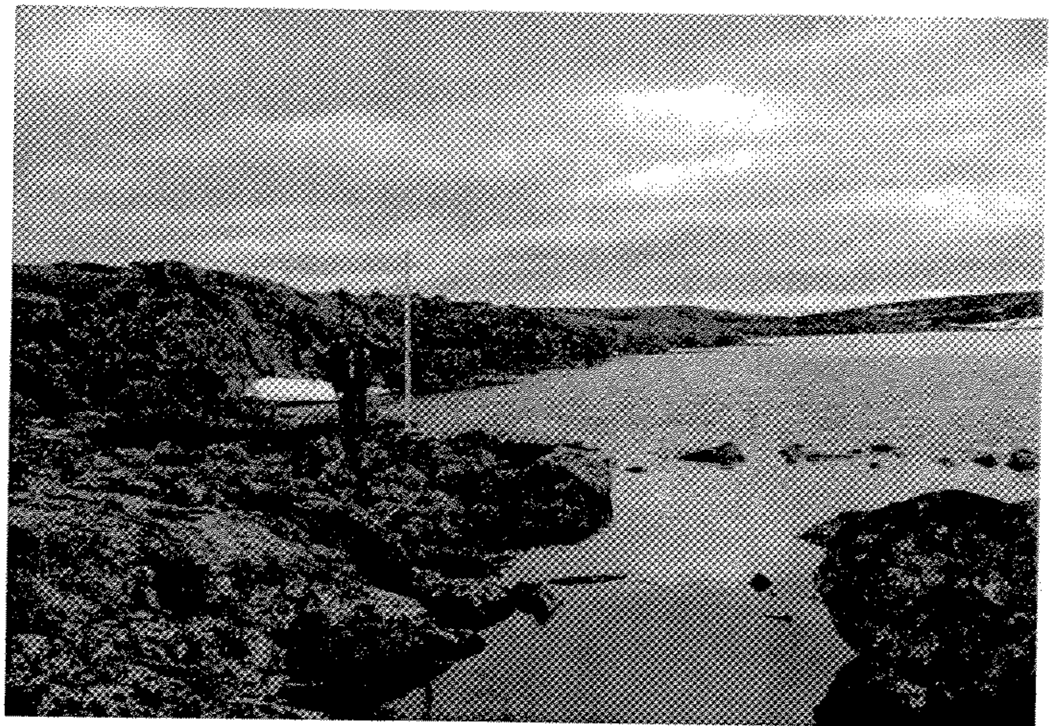
Hydrological Assessment of West Lake
Ulu Exploration Project, Nunavut
West Lake Drainage Basin
Gartner Lee
Revision: 1
Figure No.: 3

Figure 4. Water Elevation and Precipitation at West Lake 2005



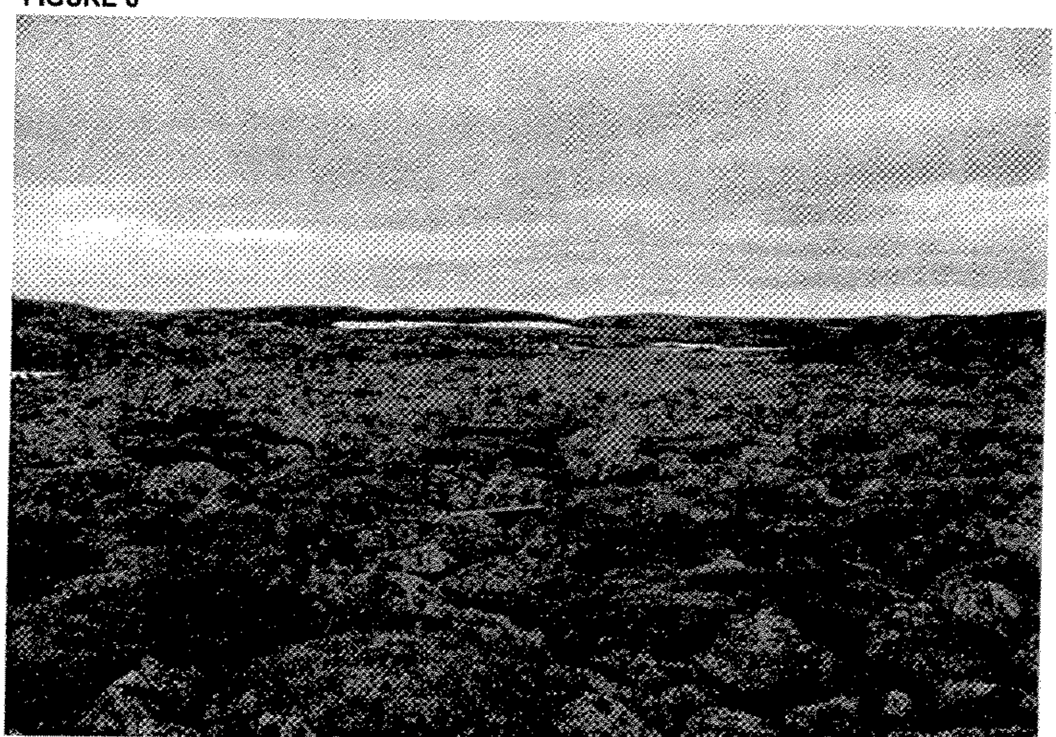
- PHOTOGRAPHS -

FIGURE 5



Outlet of West Lake, June 2005

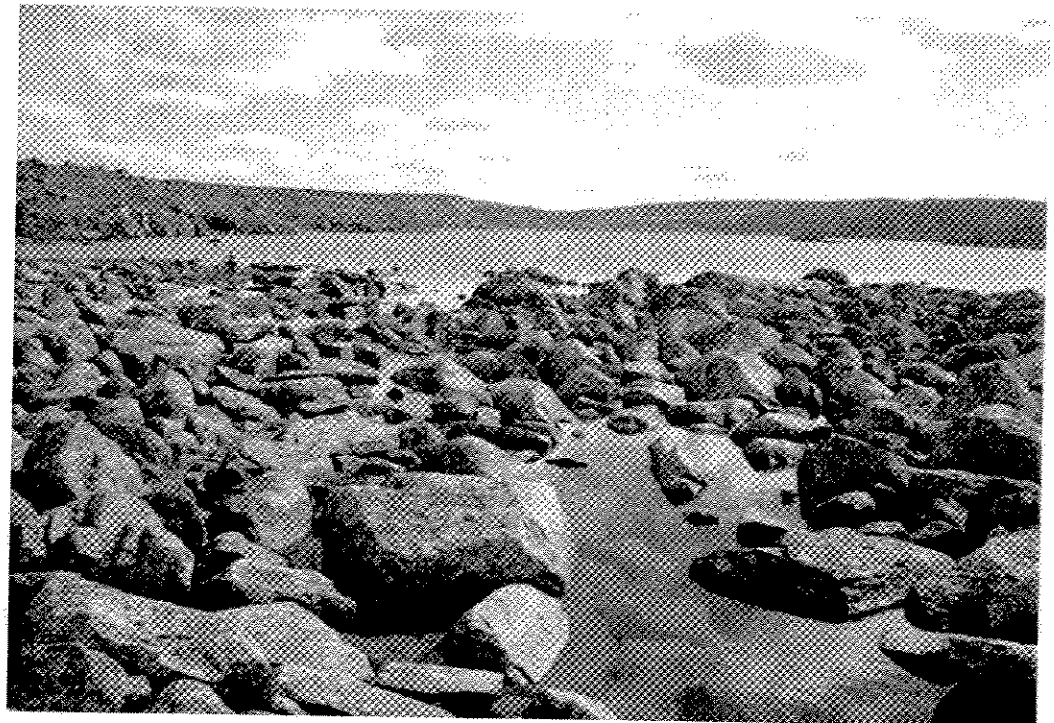
FIGURE 6



Outlet of West Lake Looking Downstream, June 2005

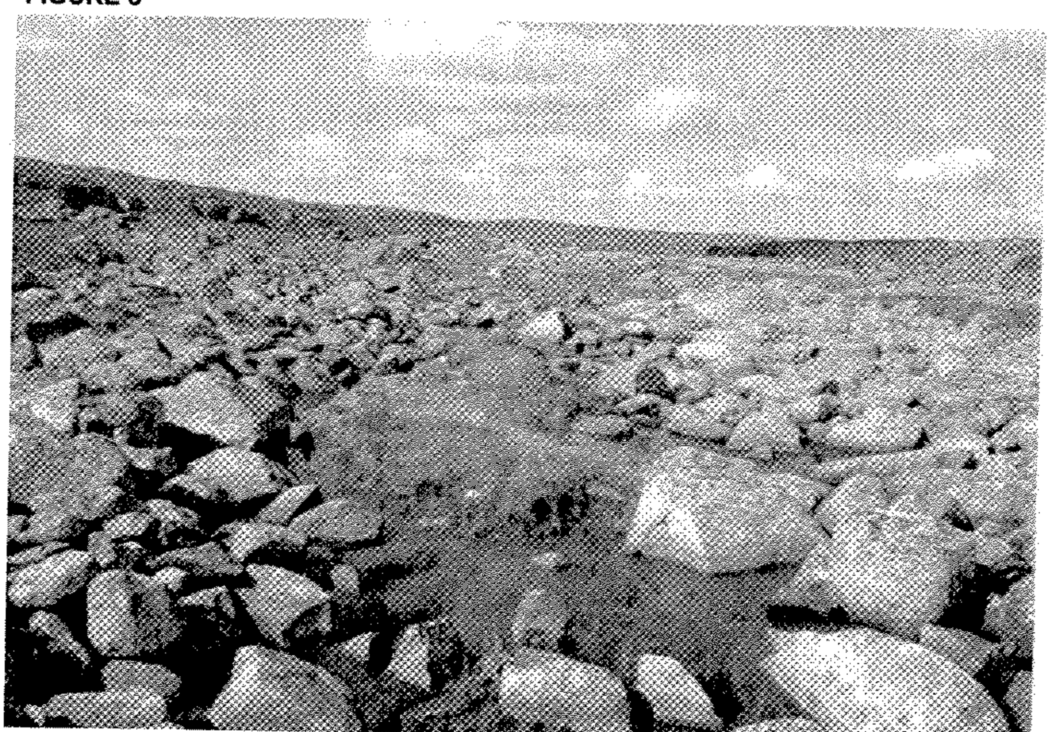
- PHOTOGRAPHS -

FIGURE 7



Outlet of West Lake, August 2005

FIGURE 8



Outlet of West Lake Looking Downstream, August 2005

Figure 9. Estimated Stage vs. Discharge for West Lake

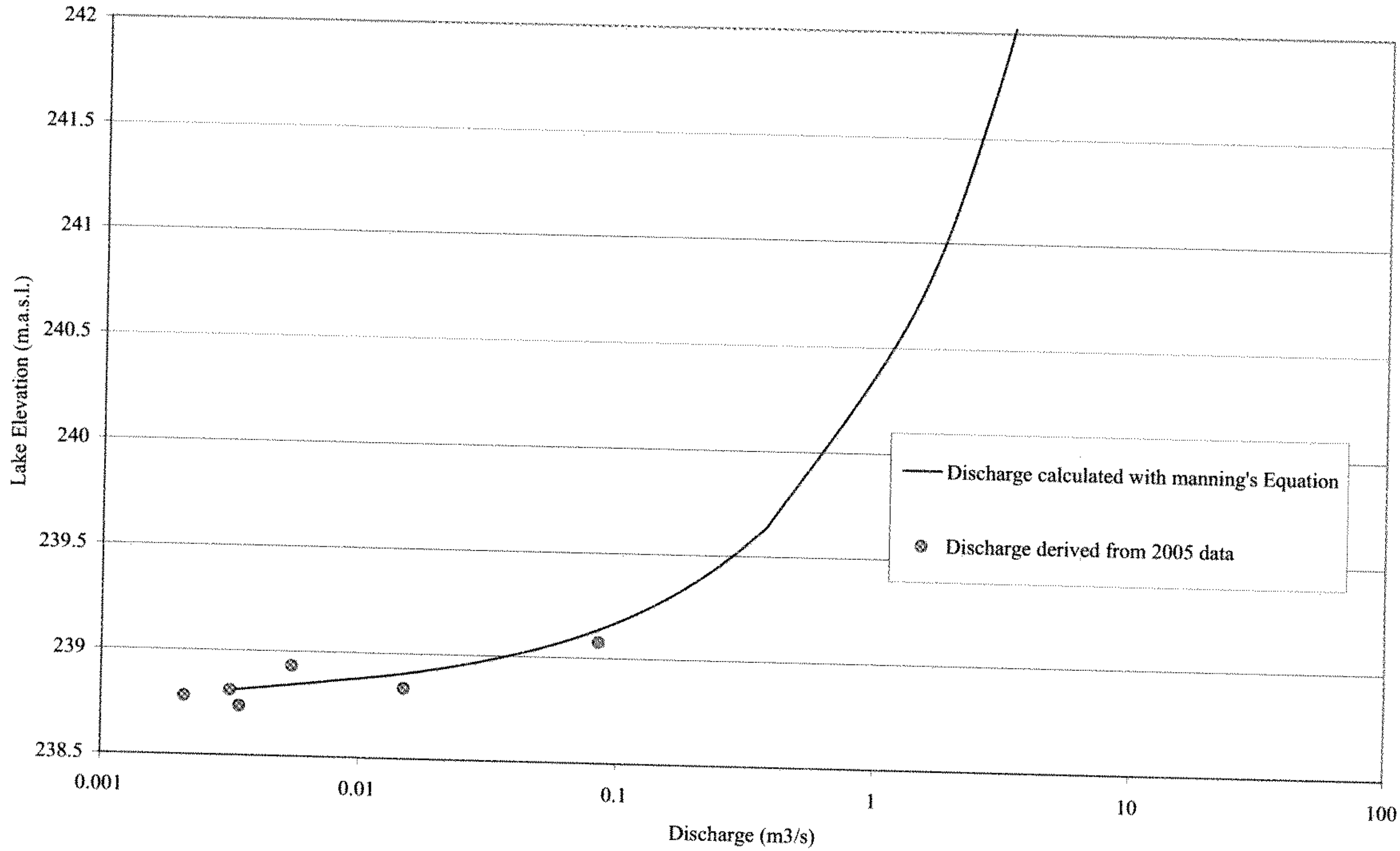
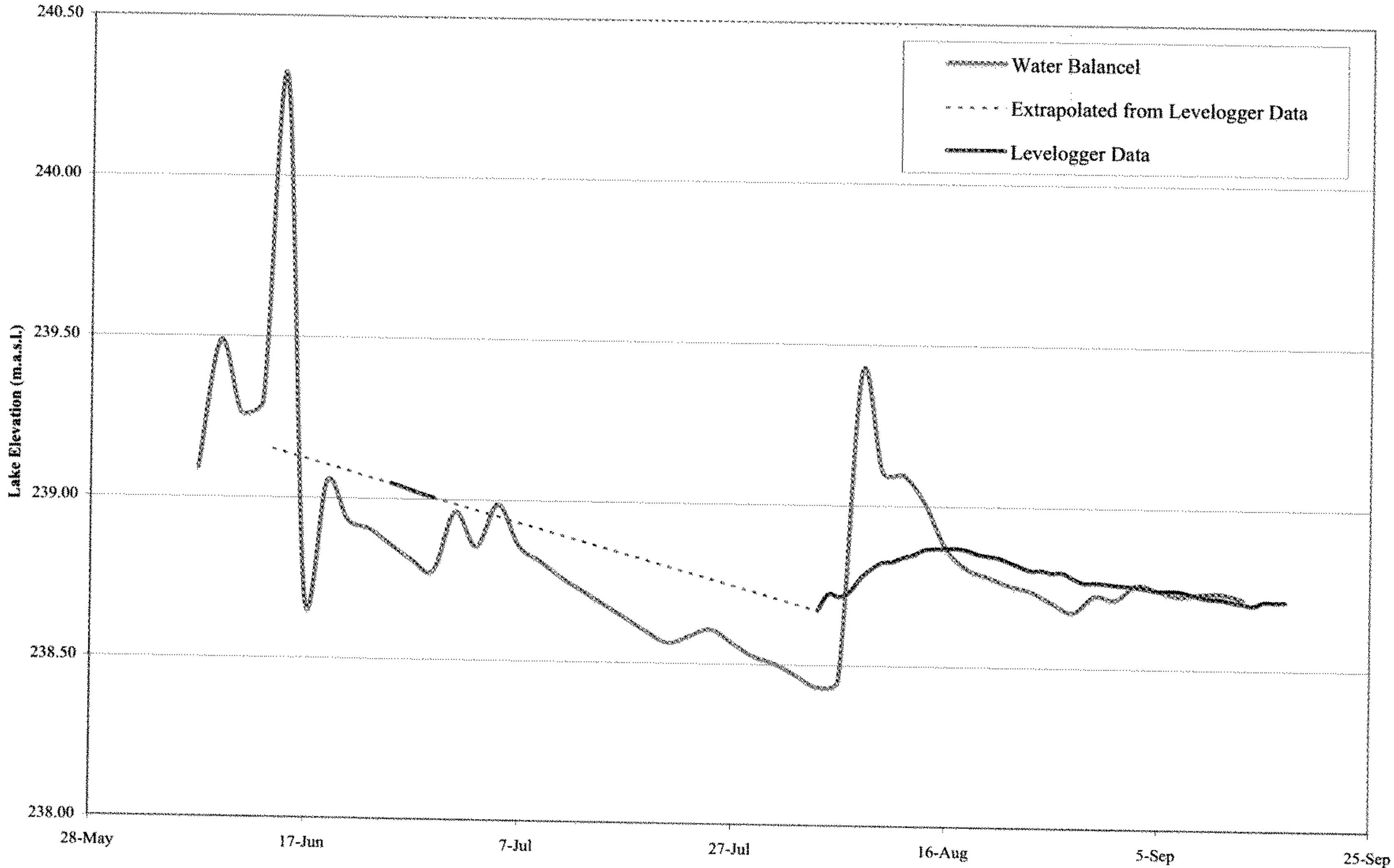


Figure 10. Predicted vs. Observed Lake Elevation 2005



Appendices

Appendix A

Camp Pumping Records - 2005

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POTABLE WATER DAILY CHECK

2005		COMMENTS	
May 13	Found in good order.	Lake Pump not installed Hauling Water.	
May 14	OK.	Hauled water, top up Tank EK	
May 15	OK.		
May 16	OK.	order Male & Female cable end for Pump EK	
			CK. By
May 17	OK.		EK
May 18	OK		EK
May 19/05			

DATE	Meter Rd GALLONS	AVERAGE DAILY USAGE	TOTAL GALLONS	CONDITION	COMMENTS	CK By
May 19/05	202861			OK	Fill Water Tank From QUARRY	EK
May 20/05	203973	1112		OK.		EK.
May 21/05				OK		EK
May 22/05				OK		EK
May 23/05				OK		EK
May 24/05				OK	Repaired leak on line connection	EK
May 25/05				OK		EK
May 26/05				O.K.		P.J.
May 27/05	203973	ESTIMATION 2100		OK	METER NOT WORKING ORDERED NEW BATTERIES	P.J.
May 28/05				O.K.		P.J.
May 29/05				O.K		P.J.
May 30/05				O.K		P.J.
May 31/05				O.K		P.J.

DATE	(GALLONS) METER RD	AVERAGE DAILY USAGE	TOTAL GALLONS	CONDITION	COMMENTS	O.K BY
June 1/05				O.K.		PJ
June 2/05				O.K.		PJ
June 3/05		ESTIMATE 2100		O.K.	STILL WAITING FOR BATTERIES FOR FLOW METER	PJ
June 4/05				O.K	"	PJ
June 5/05				O.K	"	PJ
June 6/05				O.K	"	PJ
June 7/05				OK	"	PJ
June 8/05				O.K	"	PJ
June 9/05			237573	OK	"	[illegible]
June 10/05	237573	ES 2100		OK	"	[illegible]
June 11/05				OK	"	[illegible]
June 12/05				OK	"	[illegible]
June 13/05				OK	"	[illegible]
June 14/05				OK	"	[illegible]
June 15/05			250773	OK	"	[illegible]
June 16/05	250773	EST 2400		OK	"	[illegible]
June 17/05				OK	Phone Scott pump will [illegible]	EK
June 18/05				OK	Need batteries	EK
June 19/05				OK	"	EK
June 20/05				OK	" ordered	EK
June 21/05			265173	OK		EK
June 22/05	265173	Estimate 2200	[illegible]	OK.	Replaced C-batteries Ø Meter	EK
June 23/05	2748		2748	OK		EK
June 24/05		2071	6819	OK		EK
June 25/05	8849	2030	8849	OK		EK
June 26/05	11609	2860	11609	OK		EK
June 27/05	14414	2805	14414	OK		EK

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DATE	METER READ	AVG DAILY USAGE	TOTAL	CONDITION	COMMENT	Ck
June 28/05	16100	1686	291159	OK	Totalled Water	[illegible]
29/05						
30/05	19458	3358	310617	OK		[illegible]
July/05						
1	21364	2106	312723	OK	pulled pump from lake - ice	[illegible]
2				OK		[illegible]
3				OK		[illegible]
4				OK		[illegible]
5				OK		[illegible]
6	34319	Total 13055	325778	OK		[illegible]
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						

DATE 2005	METER READ	AVG DAILY USAGE	TOTAL	CONDITION	CKD BY	COMMENTS
July 24						
25						
26						
27						
28	56446	TOTAL - 22127 1054/day	347905	OK	EK	
29	58124	1678	349583	OK	EK	
30	60680	2556	352139	OK	EK	
31	62235	1555	353694	OK	EK	
Aug 1	63709	1474	355168	OK	EK	
2	66354	2645	357813	OK	EK	
3	68316	1962	359775	OK	EK	
4	~~71164~~			OK	EK	
5	71164	2848	362623	OK	EK	
6	72532	1368	363991	OK	EK	Changed [illegible]
7	73917	1385	365376	OK	EK	
8	75559	1642	367018	OK	EK	13259 ÷ 9 days
9	76962	1403	368421	OK	EK	1473 L/day Av
10	77836	874	369295	OK	EK	
11	79205	1369	370664	OK	EK	
12	80955	1750	372414	OK	EK	
13	82097	1142	373556	OK	EK	
14	83086	989	374545	OK	EK	
15	83966	880	375425	OK	EK	
16	85163	1197	376622	OK	EK	
17	87182	2019	378641	OK	EK	
18						
19						

DATE	METER READ	AV. DAILY USAGE	TOTAL	CONDITION	COMMENT	CKED
AUG 20				OK		OK
21				OK		OK
22				OK		OK
23				OK		
24				OK		
25				OK		
26				OK		
27				OK		
28				OK		
29				OK		
30				OK		
~~Sep~~ 31				OK		
Sept 1				OK		
2				OK		
3				OK		
4				OK		
5				OK		
6				OK		
7				OK		
8	126657	39475	418116	OK	AVERAGE DAILY 1657 Brought [illegible]	EK
9	127548	891	419007	OK		EK.
10	128789	1241	420248	OK		EK.
11	130873	2048	422332	OK		EK
12	134550	3677	426009	OK		EK.
13	138193	3643	429652	OK		EK
14	141067	2874	432526	OK		EK
15	144072	3005	435531	OK		EK

DATE	METER READ	AV. DAILY USAGE	TOTAL	COND.	COMMENTS	CHKD BY.
t 16						
17	152084	8012	443543	OK		SK
18	[redacted]					
19	158731	6647	450190	OK		SK
20						
21	164928	6197	456387	OK		SK
22	167439	2511	458898	OK		SK
23	169723	2284	461182	OK		SK
24	~~[illegible]~~			OK		SK
25	178973			OK		SK
26	183226	13503	474685	OK		SK
27						
28						
29						
30						
ct 1						
2						
3						
4						
5						
6	194830	1160	486289	OK		SK
7						
8						
9						
10						
11						
12						